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ORIGINAL PAPER

The need to change pedagogies in science and technology subjects: a European perspective

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Abstract This paper evolves out of a consultancy that was carried out with the European Commission over a two year period between 2001 and 2003. A working group, set within the European Commission and comprising representatives from 15 member states, as well as associated and accession countries, stakeholders and social partners involved in maths, science and technology education, was formed. Its remit was to identify good practice in maths, science and technology education across Europe and to make recommendations for policy makers in the area. One important theme which emerged during the analysis of good practice was the need to develop the type of pedagogies which would encourage the active involvement of pupils in authentic and meaningful learning experiences within these subject domains. A series of questions relating specifically to this area was therefore incorporated into the second phase of the investigation and sent out to all participating countries. Qualitative analysis of these questionnaires was carried out. Using the results of these analyses, along with information from discussions, this paper considers the situation in Europe in respect of the introduction of what are essentially social constructivist pedagogies in the field of technology and science education. It explores some of the attempts which have been made to implement such pedagogies and more importantly the barriers to their introduction which have been identified in most countries across Europe. A consideration of research literature in the field is then used to promote the argument that teacher beliefs or theories are a crucial factor in preventing change. The role of these theories in presenting barriers to change are discussed and the implications for both policy makers and for initial teacher education are analysed.

Keywords Europe · Implicit theories · Pedagogy · Policy · Science · Technology education

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The background: a European strategy for technology and science

European-wide concern with diminishing recruitment to courses and careers in the disciplines of mathematics, science and technology resulted in an informal meeting of Ministers of Education and Ministers of Research in Uppsala (March 2001). This meeting underlined the importance of increasing recruitment to scientific and technological disciplines, including a general renewal of pedagogy and closer links to working life and industry throughout the whole educational and training system. Mathematics, science and technology (MST) was, as a consequence of that meeting, highlighted as one of the three priority areas in which the Education Council decided, on 28 May 2001, to start work, as highlighted in the conclusions of the Stockholm European Council.

At this meeting, there was general agreement that scientific and technological advancement is fundamental for the continued development of a competitive knowledge society. It was further recognised that since general and specialised scientific or technological knowledge is increasingly required in professional and daily life, in public debates, decision making and legislation, the acquisition of at least a basic understanding in these areas is increasingly necessary for all. It was further agreed that if Europe is to improve its position in the world, there must be strenuous efforts to encourage children and young people to take a greater interest in the disciplines of technology and science in particular. It was concluded that only by achieving this can the aspirations of Europe to become a major competitive and dynamic knowledge economy, capable of sustainable economic growth and greater social cohesion be realised.

It was consequently seen as essential that all countries in Europe should both encourage children and young people from the earliest possible age to take a greater interest in science and technology and ensure the satisfaction, and consequently the retention, of those who had already embarked on careers in the field. It is with issues relating to initiatives that attempt to introduce new pedagogies for technology and science at school level that this paper is concerned.

Initial findings

A working group was set up and a consultancy established with the remit of investigating the current situation across Europe and establishing and disseminating good practice in the field. This consultancy involved liaison with the European Commission and meetings with the expert representatives appointed by each of the extended European Union Countries (including the new accession countries). The MST working group started its work in September 2001 and finalised its interim report in June 2003 (Dakers & Dow, 2003).

Although all three areas of mathematics, technology and science were the focus of attention, this paper will deal with the areas of technology and science only. Although it is recognised that these are distinct and separate subjects (see for example Barlex and Pitt, 2000; Dakers, 2004; Layton, 1993), the preponderance of experts from the domain of science on the working group, along with the conflation of science and technology on many of the school curricula considered, led to generic issues relevant to both subjects being considered in tandem.

A dominant theme which emerged during the initial phase of the investigation was the importance of increasing recruitment through a change in pedagogy. This was identified by all countries as a crucial means of developing teaching methods which would not only be more effective but also more attractive to a wider range of students. This was perceived to be one, although not the only, important factor in raising both interest and achievement in both disciplines.

There was a general recognition that successful learning involves active engagement in the learning process and that in all areas, but particularly in the area of technology and science, education must be ''more concerned with interpretation and understanding than in the achievement of factual knowledge or skilled performance'' (Olson and Bruner, 1996, p. 19). The identification of pedagogies which moved away from the transmission of facts or the demonstration of skills towards the development of active, autonomous learners was therefore considered an important area for exploration. Whilst it is recognised that this resonates with most modern educational thought, it is significant that virtually all countries raised this as one of the most important issues. It is significant for two reasons. First, it became overwhelmingly clear from studies that had been carried out by almost all participating countries that students were not taking up science and technology subjects because the delivery was considered, by the students, to be out of touch with the modern technologically mediated world they now inhabit. Secondly, where countries were able to cite examples of good practice, and the working group agreed that they were examples of good practice, they all had, as a central tenet, a fundamental change in pedagogy.

In the initial stages of the working group, therefore, a number of examples of policy initiatives which were attempting to introduce more interesting, active and authentic learning approaches into the technology and science curricula were considered. Some of these were aimed at encouraging interest from an early age through the introduction of authentic hands-on learning experiences in both science and technology at the elementary stages of schooling (see for example, Barlex, 2003; Benson, 2003).

Although science was a mandatory part of the primary school curriculum in virtually all areas of Europe, however, there was generally less evidence of this being the case where technology education was concerned, with only ten European countries identifying it as a subject which was a mandatory part of the primary curriculum at the time of this research. Where it was included in the curriculum, moreover, it was most often integrated with science or was part of a more general course in environmental studies. Only Cyprus, Denmark, Estonia and England appeared to identify technology as a subject in its own right at this stage (It should be noted, however, that a few countries were not represented in the working group and these may well have technology education as a separate subject).

Some countries had made imaginative attempts to integrate both science and technology with other areas of the curriculum such as language or numeracy. Other countries argued that this tended to result in a distinctive identity for science and technology education being lost. This latter type of thinking, however, is narrow and constitutes a formal curriculum based model. Kimbell and Perry (2001), for example, argue for a more fluid and dynamic model of technology education which involves ''learning [as being] structured around projects; based on identifying and solving problems; in a range of contexts in which students transfer knowledge across different domains'' (19). It is perhaps interesting to note that science education across

Europe was identified as having a more rigid pedagogical framework than technology education.

At secondary level, attempts had been made to introduce team work and communication into the subjects through the development of collaborative working and the forging of stronger links with industry (see for example, Dakers, 2004; Head and Dakers, 2005; Hill and Smith, 2005). These industry links were proving most effective when initiated by industry rather than school-led approaches. The United States has also demonstrated that industry- led projects within authentic settings can have a positive impact upon increasing interest in the subject. The International Technology Education Association (ITEA), for example, gives many examples of the increased motivation arising from collaborations between industry and schools (ITEA, 2000), although it is also important to ensure that the types of partnerships allow for an equitable gender balance (Murphy, 2006).

Some attempts to encourage autonomous learning had been made through the opportunity for pupils to make a choice from a range of topics, the use of library research work and the provision of material suitable for different learning styles (see for example, Hill and Smith, 2005). The opportunity for pupils to work on research projects with university staff was also an important feature of policy in several countries. Entirely new subjects such as biotechnology, perceived as having greater relevance to twenty-first century were also in the process of being introduced into some curricula at secondary stage (see for example ITEA, 2000). Above all, the need to develop motivated and autonomous learners was clearly recognised through the focus in policy on the development of higher order thinking skills. Hypothesis formation, collation of evidence, synthesis, analysis and problem solving were all identified as important skills to foster in this area. (See for example, Dow, 2005; McCormick, 1997). It was clear, moreover, that the development of such skills required a paradigm shift in terms of pedagogy for both technology and science. This was identified as being of crucial importance in the responses from all participating countries.

The second stage

As the implementation of effective pedagogy in the technological and scientific disciplines emerged as an important issue during the first phase of the research, a set of questionnaires specifically designed to explore, in greater detail, the realities experienced by countries in translating policy into practice was devised. These questionnaires were distributed by the members of the working group to institutions within their own country. The criteria for selecting institutions demonstrating examples of good practice was that they should be incorporated by the education system in the country and have been subject to some established scrutiny either by research or external validation.

Participating countries were asked to provide information pertaining to three broad areas. The first involved the extent to which there was a clear recognition among both practitioners and decision makers, that there was a requirement for more effective and attractive teaching methods to be introduced. The second concerned the measures taken to support the development of new teaching methods and the role of any collaborative partnerships in this development. The

third was the identification of any challenges or difficulties which had been encountered in the attempts to implement changes in pedagogy. Although all were analysed and considered in the full report, it is with the third section of this question only, the perceived barriers to changes in pedagogy, that this paper is concerned.

Whilst it had been clear in the first phase of the analysis that the majority of participating countries were making attempts to address the issue of pedagogy in a number of interesting ways and by innovative means, it became apparent at the second stage of analysis that, there were, in reality, significant barriers to change. In almost all cases, the main barrier identified was the reluctance of teachers at all levels to adopt and implement policy changes. Although the adoption of more attractive and effective pedagogy had been identified as necessary at policy level, there was a clear perception that a significant problem existed at practitioner level with the representatives from Austria, Belgium (Flemish Community), Cyprus, the Czech Republic, Denmark, Estonia, France, Germany, Hungary, Ireland, Italy, Luxemburg, Norway, Slovakia, Slovenia and Sweden all identifying this as an important area of concern. Teachers' reluctance to change was therefore a spontaneous response from almost all countries involved.

It was apparent both from the questionnaires and from subsequent discussion sessions within the working group, that the legacy of behaviourist, transmission, whole class teaching, in which the teacher is expert and the student merely a passive recipient of knowledge, remained the dominant model in the teaching of technology and science across most of Europe.

The mechanistic processes which underlie the dominant existing model have the effect of reducing technological knowledge to small discrete components which are learned, mostly through drill and practice, and subsequently tested in situations completely devoid of any meaningful context. This was supported from the research which indicated that technology education across Europe had a vocational emphasis which tended, for the most part, to be directed towards skill acquisition in the service of trades occupations, and was taught in whole class settings with children carrying out essentially the same tasks. This type of instruction in turn results in a depersonalisation and fragmentation of the child's experience, and in its ''whole class'', assembly line production of skills, estranges children from not only the subject and each other, but from themselves as well. (Grumet 1992)

> ''Within this behaviourist inspired metaphor, the learner is a passive being whose repertoire of behaviours is determined by rewards and punishments encountered in the environment. The metaphor...has straightforward implications for instruction, namely, creating situations that elicit responses from learners and providing appropriate reinforcement for each response. Drill and practice is the epitome of instruction within this view of learning.'' (Mayor, 1992, p. 407)

It was a conclusion of the working group, therefore, that the successful implementation of major changes in pedagogy was one of the areas to be addressed in order to motivate school pupils across Europe to participate in an active and meaningful way in technology and science education. Responses further indicate a major area for concern in the implementation of new pedagogies and suggest that, for a paradigm shift to be successful, very strong teacher support mechanisms will require to be established.

The role of mediation in the learning process

The transmission model is by its nature a monologue and interaction between teacher and pupil is a one-way process. There is, however, a growing recognition in modern educational thought, that effective learning involves active participation in the learning process. Meaning cannot be transmitted but is rather constructed through the process of interaction and inquiry. This necessitates communicative action. (Bruner, 1996; Dewey, 1974; Freire, 1970; Vygotsky, 1978).

It is recognised, moreover, that learning does not take place in a vacuum. Humans do not learn simply by constructing their own realities, separate from the cultural, historical, and social environment into which they were born.

The nature of learning or mental processing involves four areas: an evolutionary process, a socio-cultural historical process, individual development and development through interaction with specific socio-cultural settings (Wells, 1999). It is social in that it involves the interaction of others. It is culturally and historically orientated through community structures which give rise to identity. A society's cultural identity is thus formed through links with its past, mediated through forms of discourse where meaning is co-constructed and reconstituted from one generation to another. This clearly moves far beyond the didactic transmission of facts and skills which, as discussed earlier, appears to be the dominant model of teaching in technology and science across Europe today.

Despite cultural differences, curricular reforms, policy developments, scientific and technological advances and developments in theories of what constitutes effective learning, the prevailing model of pedagogy in schools across Europe has clearly remained in many ways essentially unchanged. Although a number of countries have new and innovative curricula for technology education, in terms of pedagogy, these are clearly too often subverted by teachers' reluctance to change. A crucial question for the working group therefore concerned the possible reasons for the persistence of the transmission, mastery model, which is rooted in the passive, mechanistic, reductionist theories of the 1950s, in twenty-first century European schools.

Many different potential reasons were explored therefore, both through analysis of the questionnaires and discussions held during subsequent meetings of the working group, in an attempt to account for, and address, this resistance.

Perceived barriers to change

One factor that was common to a number of countries was the existence of a predominantly ageing teaching population. In these cases it was felt that an alleviation of the problem might well occur naturally as large numbers of the current teaching force reached retirement and were replaced by a younger, more energetic, motivated and dynamic population of teachers who would be more willing to embrace the necessary change. Where this was the case, it was felt that changes in pedagogy would occur naturally over a period of years.

There is evidence from research, to suggest, however, that this may, in fact, be too optimistic a view. The fact that the practices encountered by newly qualified teachers in schools exert a greater influence than the academic theories encountered in teacher education courses has long been recognised as a barrier to change (Denscombe,

1982, Zeichner & Tabachinick, 1981). More recently, moreover, Long (2004), has highlighted the almost insurmountable difficulties experienced by new teachers who do attempt to introduce innovative methods into a system in which attempts at innovation are met with either lukewarm support or outright resistance. Although Long's research is located in the United States, her concerns also find resonance across the European Union.

> ''Because they are weary of the constant battle to find a place to learn and grow, too many teachers join the status quo or leave teaching altogether. They lose hope, confidence, and, most frighteningly, a sense of themselves as knowledgeable professionals'' (Long, 2004, p. 142).

Through immersion in the existing system, today's potential innovators simply become tomorrow's subvertors of innovation and the whole cycle of resistance to change continues. As the older workforce retires, it is simply replaced by those who have become converts to the traditional transmission methods they have encountered during the early stages of their careers.

In attempting to account for the fact that so many new, enthusiastic and innovative teachers are first sucked into and subsequently maintain the status quo, Long, (2004) among other issues, highlights the problem of assessment. This was an area which again found resonance within the working group, with Cyprus, Estonia, France and the Republic of Ireland all identifying the examination system, especially at the upper secondary levels as an important barrier to change. There was a feeling expressed that as long as examinations are designed to focus on performance and the reproduction of previously learned facts, the transmission model would prevail. As long as assessment is perceived by teachers to be a means of accountability, there will be a reluctance to take the risk of abandoning tried and tested traditional methods.

In an attempt to address these difficulties therefore, the Republic of Ireland had made some changes to the system of assessment at junior secondary level. Some progress had been made through a shift of focus from formal examinations to ongoing assessment, with 35% of the final mark being allocated to course work at this stage. Although this example perhaps only defers, rather than radically changes, the impact of assessment, it was nevertheless seen a step in the right direction. France described an even more radical approach in the assessment of science at Baccalaureate level with a shift in emphasis from written theory towards the inclusion of assessment of practical work.

Both these initiatives, however, still allow for a strong emphasis to be placed on summative assessment and teacher accountability. Procedures which would enable greater focus on learning goals, creativity, risk taking, and higher order reasoning skills require to be given even greater prominence.

''Top down'' methods of promoting innovation were identified as another contributory factor to teacher resistance to change. Austria, for example noted the scepticism of teachers to ''top-down'' models of reform, the lack of coordination between government driven and practitioner driven initiatives, along with a deterioration in the working conditions of teachers as important factors in this respect.

That initiatives developed at policy level either do not translate into practice at classroom level or are short lived is well known within the field of education.

There is a growing recognition, therefore, that for teachers to have a sense of ownership of new initiatives, it is necessary to regard them as equal partners at all stages of discussion, planning implementation and evaluation. Although Scotland had no representation on the working group, there may be valuable lessons to learn from a recent Scottish Executive funded initiative, known as ''Assessment is *for* Learning'', where the emphasis is on the *for* and less on the *what*. This initiative has adopted just such an approach, with teachers actively engaged in close collaboration with policy makers and researchers, and appears, to date, to be having an effect on changing, not just assessment, but through this, the pedagogy of teachers across the curriculum in primary and secondary schools (Hallam et al., 2003). While ongoing evaluation of the programme will be necessary to determine its impact on pedagogy in the longer term, there may well be valuable lessons from this approach for the development of more effective pedagogies in science and technology across Europe.

A lack of appropriate support in the form of pre-service education, in-service training or suitable resources was also identified as a barrier by the Czech Republic, Denmark, Estonia, the Belgian Flemish Community, Germany, Hungary, Italy, Slovakia, Slovenia and Sweden. Whereas some countries such as Estonia, Hungary, Slovakia and Slovenia particularly emphasised the need for resources in the form of new, up-to-date text books and materials, there is again evidence that this may not be sufficient to ensure a change in practice. The Belgian Flemish Community, for example noted that even where good practice materials were provided, the difficulty of convincing teachers of their effectiveness remained. In Norway, moreover, the perception existed that it was difficult to persuade teachers that the use of different methods would result in more motivated and competent students in the field of science and technology. As the status quo was perceived to be successful, there was little impetus for change.

Implicit theories

It was evident that teacher resistance to change was perceived as a real and persistent problem across Europe, at least in relation to pedagogy in technology and science. Although a number of possible contributory factors were identified, it seems important to explore another and more deeply rooted barrier to change before trying to explore the most effective means of change. This can be done by considering the role of implicit theories in influencing practice at classroom level.

The problem of translating educational theory into practice has been long recognised and any attempt to address this must first fully consider why this should be so.

One significant and important aspect of resistance, which although recognised, has been given insufficient attention by policy makers, is the underlying assumptions which teachers hold about the nature of effective teaching and learning. There certainly appeared to be evidence to support this from a number of countries across Europe.

The role of these intuitive, tacit, or implicit assumptions or theories which may differ markedly from espoused theories and which are often not articulated and which may be evident only in action, has been investigated in a number of areas with direct relevance to the classroom. Kennedy (1997) suggests, for example, that the types of implicit beliefs held by teachers can strongly influence fundamental issues

such as reasons given for variation in academic performance, the role of education, the nature of effective pedagogy, and notions of right and wrong in the classroom. Dweck (1999) has explored the importance of implicit theories of personality in attributions that teachers make in respect of pupil behaviour, and both Dweck, Chui, and Hong (1995) and Sternberg (1985) have investigated the differences between implicit and explicit theories surrounding the constructs of intelligence, personality and creativity. Theories of epistemology (e.g. Schommer-Atkins, 2002) concerning beliefs about knowledge, such as how it is defined, constructed and evaluated, where it resides and how it occurs, can also be held implicitly and therefore have important implications for how technology and science education is constructed and presented.

Difficulties in affecting change may also be a function of the enduring nature of these implicit theories which teachers hold. Whereas Dweck (1999) provides some evidence to suggest that implicit theories *can* be changed, at least temporarily under laboratory conditions, the findings of others in more natural settings would appear to contradict this. Argyris and Schon (1976) for example, suggest that change is difficult as implicit theories form barriers which prevent the understanding and adoption of new ideas or ways of thinking

> ''...the trouble people have in learning new theories may stem not so much from the inherent difficulty of the new theories as from existing theories that people have that already determine practice'' (1976: viii preface)

This enduring nature is further highlighted by Kennedy (1997) who also stresses their role in the evaluation of new information. In this respect, existing implicit theories form structural frameworks within which new information is selected and constructed. Thus, whilst new ideas which are compatible with an overall existing framework will be easily and unconsciously assimilated, those which appear challenging or incompatible will be automatically filtered out or dismissed without consideration. Not only do past experiences create implicit theories, but these, once generated, create frameworks through which further experiences are constructed.

It seems clear therefore that these implicit theories have serious implications for classroom practice and ''can be ignored only at the innovators peril'' (Clarke and Peterson, 1986, cited in Yerrick, Parke, & Nugent 1997).

The role of policy in affecting change

Teacher resistance to change is clearly a complex and multi-faceted problem to which there is no single, simple solution. Yet if pedagogy is to change in order to make the subjects of technology and science more attractive, effective and relevant to today's young people, then solutions must surely be found. It would seem then that a coherent and cohesive range of varied and intensive initiatives involving close collaboration between policy makers, teacher educators, researchers, and practitioners may provide the best hope of effecting real and lasting change.

One area that could clearly be addressed through such collaboration is assessment. As long as governments remain obsessed with measurement for accountability purposes, the culture of mastery learning seems likely to remain. Teaching to the test in order to inflate results puts the focus on performance rather than the processes of

learning. Until this is recognised it seems likely that this particular aspect of teacher resistance to change in pedagogy will persist, even when this is in conflict with implicit theories held. Although the traditional approach may give the appearance of short term success for some, the introduction of forms of assessment which promote the adoption of learning goals rather than performance goals are more likely to result in more meaningful learning, more active involvement, and consequently greater increases in both achievement and interest over time.

At the level of policy, one way ahead may lie in the type of solution already adopted in relation to assessment by countries such as Ireland, France and Austria. An important next stage, however, would be the introduction of even more radical changes in assessment than those so far introduced, with a move towards the adoption of a system in which the main focus is on evaluation of processes rather than products of learning, where assessment is used to inform students of their present level of understanding of scientific and technological concepts, rather than the present focus on the products of learning-knowledge and understanding translated into the recall of previously learned facts.

Removing, or at least reducing the pressures of assessment on teachers might in addition allow for the important elements of uncertainty, experimentation and creativity to be more easily incorporated into the technology and science curriculum. Instead of demonstration and replication of already known processes, a spirit of true scientific and technological inquiry and exploration might be allowed to develop. In this context, teachers, instead of being the transmitters of existing knowledge could be encouraged to become, along with their pupils, part of a community of enquiry, a team which explores the unknown and uncertain together. Methods that are directed towards the assessment of creativity and innovation are now well documented in work recently undertaken by Kimbell (2006). Adoption of these could go some way to changing the actions of teachers and thereby to challenging their existing implicit beliefs.

A parallel change in the curriculum towards a focus on relevant current events and issues in the technology and science fields, would perhaps not only ensure that teachers and students were learning together but also help students develop the important idea that technological and scientific endeavour is an uncertain and tentative process. Thus the development of courses dealing with technological literacy could clearly play an important part in this as teachers and pupils together explore the impact of new technologies on society.

Of vital importance in all these areas is the incorporation of the type of genuinely collaborative models of change identified by Austria and presently being developed in Scotland. When change is perceived as imposed from above, it is more likely to be rejected or absorbed into existing implicit frameworks. However, when teachers are invited to form part of a community of enquiry along with policy makers and researchers, where all are perceived as learners with important contributions to make to the process, reform is no longer imposed but actively pursued.

Powerful changes in both assessment and pedagogy can ensue as teachers, in equal partnership with policy makers and researchers are encouraged to take ownership of the change and to research the impact of these changes in their own classrooms. Black, Harrison, Lee, Marshall, and William (2003) demonstrate that although changes in practice, when affected by such means of collaborative enquiry can exist at different levels, (at some levels leaving implicit theories intact), at the deepest level, change permeates *all* aspects of a teacher's thinking and consequently

has a profound impact on all aspects of pedagogy and beliefs- even those which are implicit.

The role of initial teacher education in supporting change

Although changes in policy may go a long way to affecting change, the experience of the majority of countries across Europe indicated that policy measures in themselves are insufficient and even collaborative initiatives will fail to impact on all. A number of countries were therefore also giving serious consideration to how both pre-service and in-service provision for teachers could be improved to facilitate changes in thinking.

Since research clearly demonstrates the impact of implicit theories as a barrier to change, an important way forward for initial teacher institutions is to give pre-service (and in-service) teachers opportunities to explore and make explicit their deeply embedded implicit theories, thus enhancing self knowledge and making a critical self analysis of practice more possible.

A range of methods exist by which implicit theories can be brought into consciousness. These include standardised questionnaires specifically devised to address particular areas such as intelligence and personality (e.g. Dweck, 1999; Sternberg, 1985), the use of concept generation exercises such as the Kelly Repertory Grid (Solas, 1992; Hillier, 1998) narrative studies (Beattie, 1995), learning journals (Johnston, 2004) and explorations of the metaphors that are used to describe the learning process (Bullough, 1991; Inbar, 1996; Yero 2002)

That the elicitation of implicit theories by whichever means does not *in itself* result in significant changes in practice, however, has been clearly demonstrated by research. Recognising the lack of impact of one-day courses on teacher practice, for example, Yerrick et al. (1997) explored the effect of an intensive 2 week course on the thinking and practice of teachers. Implicit theories were first elicited by means of intensive interviews, during which teachers were asked to reflect on the nature of teaching and their own past experiences. Interestingly, and in line with findings from across Europe, the overwhelmingly predominant implicit belief elicited was that which supported a transmission model of teaching.

An intensive 2 week workshop in which participants became learners in inquiry sessions while tutors modelled the use of dialogue and similar transformational teaching methods was specifically designed by the researchers in an attempt to affect changes in both thinking and pedagogy. The intended outcome was the promotion of independent, autonomous learning and a deeper understanding of concepts by situating learning within authentic and current contexts—exactly the outcomes desired by policy makers across Europe, and entirely in line with most modern thinking for the delivery of technology education. The findings suggest, however, that despite evident changes in teacher *talk* (i.e. espoused theories) about teaching, curriculum content and assessment at the end of the 2 week period, implicit beliefs not only remained intact, but had been used, as Kennedy (*op cit*) has suggested to construct new knowledge within the existing framework of beliefs.

> '' While.... educators embrace the replacing of factual treatment of knowledge and objective testing with more inquiry-based teaching steeped in learning

> theory and philosophical treatment, teachers' belief systems can keep teachers from even recognising these differences. Teachers who are targets for upcoming reform efforts may enter the profession embracing a transmission model of teaching that filters out other messages which thus makes change unlikely.'' (Yerrick et al. 1997, p. 156)

If change in practice is to be implemented successfully across Europe, it will clearly not be sufficient either to simply elicit or explore the implicit theories held by entrants to courses in Initial Teacher Education or teachers who attend in-service courses intended to promote pedagogical reform. Whilst such measures may help to make implicit theories open to examination and question, this on its own will not necessarily affect any deep or lasting change in practice. This is clearly partly because of the deep rooted nature of beliefs which act as filters for incoming information, the strength of which cannot be underestimated and partly because of the complex interaction of implicit beliefs and the context in which they are operating.

Wells (1999) suggests, for example that the implementation of change is further complicated by the conflict that may exist between teacher beliefs and perceived external requirements. Further difficulties arise when teachers try to adopt innovatory practices which are in keeping with their implicit theories but which are not supported by external administrators, and indeed the wider community.

This viewpoint was also apparent in perceptions of technology and science education across most of Europe. The teachers who *are* attempting to implement new pedagogies are often being expected to change their practice within a context where instructive discourse is dominant and therefore shapes the educational world. This epistemological framework also poses a serious challenge to the delivery of a modern and exciting technology and science curriculum.

Although, eliciting implicit theories is in itself unlikely to be sufficient therefore, it is an important first step. Through an exploration of the impact of past experience for example, teachers may reach a deeper understanding on the influences on their current practice. The keeping of reflective journals of teaching experience, with opportunities to analyse the discourse in these will also help to deconstruct implicit beliefs and their impact upon classroom practice, as will opportunities to engage in an analysis of practice through reflective observation using video-taped lessons. Although research clearly demonstrates the difficulties of changing implicit theories over short periods of time, making such processes a major and integral part of teacher education courses could go some way to raising awareness of their impact on practice. If these measures are then combined with the types of collaborative measures already described in which policy makers, teachers, industry and researchers work together as equal partners, there may be greater hope of progress for the future.

External control is central to the transmission model of teaching and can be difficult for teachers to relinquish. Educators of student teachers must also therefore explore their *own* implicit theories in this respect. Although social constructivist methods were *espoused* in all examples of Initial Teacher Education initiatives across Europe, it is likely that the reality of the educational experience for students within these institutions involves such aspects as limited subject choice, whole class lectures, an emphasis on performance through summative assessment and a tight control of timetabling- all of which *implicitly* suggest and transmit a very different

message of what constitutes effective teaching and learning from that which is espoused. Those in initial teacher education must therefore also examine whether or not the theories that they espouse are in conflict with the implicit theories which are evident in action.

Changing pedagogical practice in technology and science within the European context will clearly not be an easy task. Change will require a double-pronged attack which not only explicitly and intensively addresses the implicit theories which teachers (and indeed teacher educators) hold, but simultaneously introduces the kind of policy measures which will not only challenge implicit beliefs but encourage teacher ownership of change. It was very evident from both responses to the questionnaires and discussion within the working group, that without radical and concerted efforts to affect change, increasing pupil recruitment to technology and science subjects across Europe through the development of more attractive and effective teaching methods suitable for the twenty-first century may well prove to be nothing more than an elusive dream.

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